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## GLIDE HEAD FOR ASPERITY DETECTION

### CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority to provisional patent application Serial No. 60/082,244, 5 entitled "A Novel Glide Head," filed on April 16, 1998.

### BACKGROUND OF THE INVENTION

The present invention relates generally to glide heads for evaluating glide quality of a disc 10 surface, and to related methods. More particularly, the present invention relates to a glide head with a thermal transducer for detecting defects on a disc surface.

Disc drives are used for storing 15 information, typically as magnetically encoded data, and more recently as optically encoded data, on a disc surface. The storage and retrieval operations generally involve "flying" a read and/or write head over the surface. As storage densities increase, the 20 fly height of the heads over the disc surfaces generally are decreased. Consequently, defect heights on the discs must decrease proportionally to reduce or eliminate contacts between the head and disc that could damage the head, the disc or both.

Glide tests are used to determine if a given 25 disc meets the required glide quality. The glide quality of a disc is related to the disc smoothness, although other defects also may alter glide quality.

In particular, tests are used by computer disc 30 manufacturers to control and assure the quality of the disc media. Generally, all hard drive discs are tested before shipment. During a glide test, the test head or slider flies over a disc surface generally at

a predetermined clearance from the disc surface, known as the glide height or fly height. The glide head or slider includes a transducer that detects interactions between the disc and the glide head due to defects on  
5 the disc surface.

The glide heads are selectively moved under the control of electronic circuitry to any one of a plurality of circular, concentric data tracks on the disc surface by an actuator device. Each slider body  
10 includes an air bearing surface (ABS). As the disc rotates, the disc drags air beneath the ABS, which develops a lifting force that causes the glide head to lift and fly above the disc surface. Glide heads generally are designed to have a fly height that is  
15 sensitive to the linear velocity of the disc surface relative to the glide head. For example, to detect smaller defects on a disc surface, the disc velocity can be decreased to decrease the fly height of the glide head.

20 A transducer can be used to detect contacts between the glide head and defects. Generally, piezoelectric transducers are used to detect vibrations that result from contact between a glide head and a disc defect. Using glide heads, the  
25 process of mapping disc defects while changing the fly height of the head requires several scans at different head fly heights to map the entire range of defects. As the speed is changed, the response of the specially designed glide head also changes. For example, if the  
30 speed is reduced, the energy of the impact is reduced, thus making it more difficult to calibrate to the defect size and height.

SUMMARY OF THE INVENTION

In one aspect, the invention features an asperity detection slider including an air bearing surface and a thermal transducer. The thermal transducer is generally planar and is oriented along  
5 the air-bearing surface.

In another aspect the invention features, a method of producing an asperity detection slider, the method including depositing a thermal transducer along an air bearing surface of the slider.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic, top perspective view of a glide tester incorporating an improved glide head, where a disc is shown with phantom lines such that structure below the disc is visible.

15 Fig. 2 is a bottom view of an embodiment of an slider with a thermal transducer located on the air bearing surface.

20 Fig. 3 is a bottom view of another embodiment of an slider where a thermal transducer is located on the air bearing surface away from the slider's rear edge.

25 Fig. 4 is a bottom view of an embodiment of an slider where a thermal transducer covers a substantial portion of a rail on the air bearing surface.

Fig. 5 is a bottom view of a slider having two different configurations of multiple thermal transducers located along a rail on the air bearing surface.

30 Fig. 6 is a bottom view of an slider having an alternative configuration of multiple thermal transducers located along a rail on the air bearing surface.

Fig. 7 is a schematic perspective view of an slider having both a thermal transducer and a piezoelectric transducer.

5 Fig. 8 is a schematic, fragmentary perspective view of a wafer with thermal transducers located on the surface of the wafer at locations that are contoured to be an air bearing surface of the ultimate sliders.

10 Fig. 9 is a schematic, perspective view of an slider with a thermal transducer along a rail on the air bearing surface and electrically conductive pads deposited on a rear edge prior to the addition of protective material over the pads.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 By placing a thermal transducer as an defect/asperity sensor on the air bearing surface of a slider/glide head, glide testing can be performed efficiently with a high sensitivity. After a defect strikes the thermal transducer, a resistance spike is  
20 detected to provide a signature that a defect has contacted the glide head. Furthermore, thermal transducers oriented along the air bearing surface can present a large contact area on the air bearing surface. Thus, a glide test can be performed  
25 efficiently since asperities with a greater range of heights strike the thermal transducer when contacting the glide head. A plurality of thermal transducers on the air bearing surface can be used to assess the distribution of defect heights.

30 Glide tests performed with piezoelectric (PZT) transducers can be accomplished efficiently since defects with a wide range of heights are detected in one pass over a section of the disc. It

is believed, though, that glide heads with PZT transducers may give positive readings when defects pass near the glide head even when they do not strike.

Thus, PZT based glide heads may result in false  
5 positive readings for defects.

Magnetoresistive (MR) type sensors used in read/write heads can operate as thermal transducers. In contrast with defect sensors placed on the air bearing surface, MR sensors in read/write heads are  
10 located on a side of the slider adjacent the air bearing surface and have only an edge of the MR sensor in contact with the air bearing surface. After contact with an defect, the heat generated by the contact changes the resistive properties of the MR  
15 sensor. As a result, the measurement of the resistance of the MR transducer biased by a constant current source is distorted by a spike and subsequent decay. Because of the narrow profile along the air bearing surface presented by the MR sensor in a  
20 read/write head, few defects will strike the glide head at the MR sensor with the MR sensor at the trailing edge side. Collisions with defects that strike such a glide head away from the MR sensor may not produce a voltage spike in the resistance  
25 measurement.

Thus, thermal defect detection methods using either MR read/write heads having a narrow MR sensor track width, or asperity detection sliders adapted from MR read/write head designs having an increased MR  
30 sensor track width have inherent limitations. Using MR read/write heads, with track widths typically less than 2.5  $\mu\text{m}$ , the time for a full surface scan is extremely time consuming. Furthermore, standard MR

read/write heads of the type used in disc drive systems are designed to reduce sensitivity to thermal asperity response by having increased fly heights and/or MR transducer recessed with respect to the air bearing surface. Specially designed thermal asperity heads can reduce the surface scan time and increase the thermal asperity response by using a somewhat wider MR sensor track, for example, 60  $\mu$ M. This wider MR sensor track still only covers a very small portion of the slider air bearing surface.

It is believed that thermal asperity detectors do not respond to near misses between a defect and the glide head. In particular, contact between the thermal transducer and a defect produces a characteristic resistance spike that may not be produced by contact between other portions of the slider and the defect. Thus, thermal transducers by their nature are inherently very sensitive to contact with a defect, while rarely giving a false positive reading. Thermal transducers placed on the air-bearing surface can take advantage of both a high sensitivity with respect to detecting actual contact with an asperity and an ability to detect simultaneously a larger range of defect heights. In this way, the glide test can be performed with an efficiency comparable to PZT based glide tests while taking advantage of the high sensitivity and specificity obtained with a thermal transducer.

Under previous practices for slider/glide head production, one of the cut surfaces of the slider formed from a wafer is formed into the air-bearing surface. If a cut surface is formed into the air bearing surface, a thermal transducer formed along an

edge of the slider can be placed on the wafer prior to cutting the slider from the wafer. A novel approach to the production of glide heads involves using a very smooth surface of the wafer as the air bearing surface. The cut edges of the wafer become the sides of the slider.

Using this alternative slider production procedure, thermal transducers can be placed on the air-bearing surface at the wafer level prior to cutting the individual sliders. Thermal transducer application on the air bearing surface provides for the performance of many processing steps at the wafer level. In particular, the placement of the thermal transducer on the air bearing surface can be performed more efficiently at the wafer level prior to cutting individual sliders from the wafer.

The thermal transducers are made from materials that alter their electrical resistance in response to a temperature change. To complete the asperity detector, the thermal transducer is connected to a circuit that provides for the measurement of the electrical resistance of the material in the transducer on the air bearing surface. To form the electrical circuit, electrical conducting pads can be placed along an edge of the slider to connect electrically the air bearing surface with the top surface of the slider. A particular thermal transducer is connected to two electrical pads to form a circuit through the transducer. The electrical circuit for resistance measurement is completed with connections to the electrical pads at the top of the slider body.

The air bearing surface of the slider

generally includes contoured portions such as rails for aerodynamic performance. The thermal transducers generally are placed on an extended portion of the surface such that they will provide the point of contact with an asperity. A single large transducer can provide for defect detection over a larger range of defect heights. The use of multiple thermal transducers can provide for grading of asperities, as described further below. Thus, selection of the number and placement of the thermal transducers involves a balance between the processing complexity and the amount of information desired about the nature of the asperities. In preferred embodiment, the one or more thermal transducers cover an area of the air bearing surface from about  $0.05 \text{ mm}^2$  to about  $5.0 \text{ mm}^2$ .

Referring to Fig. 1, a glide tester 100 includes a glide spinstand 102, an arm assembly drive 104, a suspension/glide head assembly 106 and a controller 108. Glide spinstand 102 includes a spindle motor 110 and disc 114, shown in phantom lines. Spindle motor 110 supports and spins disc 114.

Arm assembly drive 104 has a motorized drive 120 and an arm 122. Arm 122 has a support portion 124 that connects with motorized drive 120 and an extension portion 126 that extends over disc 114. Motorized drive 120 moves arm 122 either by lateral motion or by rotational motion to alter the radial position of suspension/glide head assembly 106 along a disc 114 mounted on glide spinstand 102.

Suspension/glide head assembly 106 generally includes suspension 128, gimbal 130 and glide head 132. Suspension 128 connects with arm 122. Glide head 132 is connected to suspension 128 by way of

gimbal 130. Suspension 128 and gimbal 130 can have a variety of designs including conventional structures.

Controller 108 is connected to arm assembly drive 104 and spindle motor 110. Controller 108 correlates the position of arm 126 with the rotational speed of the spindle motor to maintain an approximately constant linear speed of slider 132 relative to the disc surface. Also, controller 108 correlates impact information detected by glide head 132 with a defect location on disc 114.

An embodiment of glide head/slider 132 is depicted in Fig. 2. Glide head 132 includes two rails 150, 152 on air bearing surface 154. A thermal transducer 156 is located on rail 150. Thermal transducer 156 is located near rear edge 158 of glide head 132. Electrically conducting pads 160, 162 provide electrical contact between thermal transducer 156 and the top of glide head 132. Pads 160, 162 are connected to a measurement circuit at the top of the glide head such that the electrical resistance of thermal transducer 156 can be monitored. To improve the aerodynamic performance, steps 164, 166 are located near front edge 168 of glide head 132. The contoured features on the air bearing surface can be varied to achieve a desired aerodynamic performance of the glide head.

Thermal transducer 156 generally is made from material with an electrical resistance that varies with temperature. For example, materials such as NiFe alloy used to form magnetoresistive transducers also exhibit a thermal resistance effect.

Preferred materials for producing the thermal transducers have a resistance that is relatively

insensitive to magnetic fields since the defect measurement should not be sensitive to the magnetic field near the glide head. Preferred materials for forming the thermal transducer include, for example, 5 nickel (Ni). Electrically conductive pads 160, 162 generally are made of conducting metal, alloy or metal compound. Electrically conductive pads 160, 162 are made preferably from gold.

The back edge of glide head 132 generally 10 flies closer to the surface of the disc than the front edge. The pitch of glide head 132 is due to aerodynamic forces. Therefore, placement of the thermal transducer near the rear edge of the glide head provides for the detection of smaller asperities 15 for a given fly height. Nevertheless, if desired the thermal transducer can be placed away from the rear edge. Such an alternative embodiment is depicted in Fig. 3. Thermal transducer 180 is located on rail 182. Electrical conduction strips 184, 186 provide 20 for electrical conduction between thermal transducer 180 and electrical conduction pads 188, 190. Electrical conduction pads 188, 190 provide a path of electrical conduction between strips 184, 186 and the top of glide head 132. Electrical conduction strips 25 184, 186 can be produced from electrically conductive metal, alloys, metal compounds or combinations thereof.

If the thermal transducers covers a substantial portion of the length of the glide head, 30 defects with a wide range of heights strike the thermal transducers to produce a spike in the resistance of the transducer rather than striking a portion of the air bearing surface away from a

transducer. Thus, another alternative embodiment of a glide head 132 is shown in Fig. 4. Thermal transducer 200 covers substantially all of rail 202 up to step 204. Thermal transducer 200 is in electrical contact 5 with electrically conductive pads 206, 208.

A plurality of thermal transducers can be used on a single glide head. In preferred embodiments, a plurality of thermal transducers cover a substantial portion of the length of the glide head. 10 In particular, the plurality of transducers can cover a substantial portion of a rail or other contour on the air bearing surface. The use of a suitably placed plurality of thermal transducers provide for the grading of defects by height. In other words, defects 15 with different ranges of heights strike the glide head at different portions of the air bearing surface due to the pitch of the slide during use. Identification of the transducer that is struck indicates that the asperity has a height within a particular range.

20 Two embodiments for the placement of multiple transducers are indicated in Fig. 5. In the slider 132 of Fig. 5, rail 250 has one configuration of multiple transducers while rail 252 has a second configuration. The placement of thermal transducers 25 on more than one rail or other contour provides for the simultaneous detection of asperities on two portions of the disc surface. The motion of the slider across the disc surface can be adjusted accordingly.

30 Thermal transducers 254, 256, 258 are located on rail 250. Pad 260 and strip 262 provide electrical contact to a common ground for transducers 254, 256, 258. The use of a common ground reduces the

space needed for electrical conduction strips and reduces processing related to the deposition of conduction strips. Pads 264, 266, 268 and strips 270, 272, 274 provide electrical conduction to transducers 5 254, 256, 258, respectively, for resistance measurements.

Thermal transducers 290, 292 are located on rail 252. Pads 294, 296 and conduction strips 298, 300 provide electrical connections to transducer 290. 10 Similarly, pads 302, 304 and conduction strips 306, 308 provide electrical connections to transducer 292. In contrast with transducers 254, 256, 258, transducers 290, 292 do not share a common ground.

An alternative configuration of slider 132 having multiple thermal transducers is depicted in 15 Fig. 6. Thermal transducers 320, 322, 324, 326 are located on rail 328. Transducers 320, 322, 324, 326 share a common electrical ground provided by pad 330 and conductive strip 332. Pads 340, 342, 344, 346 20 provide the remaining electrical connections for transducers 320, 322, 324, 326, respectively, with the top of slider 132.

Pads 340, 342, 344, 346 are in electrical contact with conductive strips 348, 350, 352, 354. 25 Conductive strips 348, 350, 352, 354 are located on plateau 356. Since transducers 320, 322, 324, 326 are located on rail 328, electrical connection between the transducers and strips 348, 350, 352, 354 is established by electrically conductive pads 360, 362, 30 364, 366. The placement of conductive strips 248, 350, 352, 354 on plateau 356 provides for the coverage of a greater portion of the surface of rail 328 with thermal transducers, although additional processing

may be required to produce pads 360, 362, 364, 368 that provide electrical conduction between plateau 356 and rail 328.

A slider with a thermal transducer on the  
5 air bearing surface can also have one or more additional transducers for the detection of defects. The use of multiple types of transducers provides for a comparison between measurements made with different types and/or configurations of transducers. For  
10 example, thermal transducers which are particularly sensitive to actual strikes with an asperity can be used to evaluate whether piezoelectric transducers produce false positive signals from near misses with asperities.

Moreover, multiple types of transducers for  
15 detecting defects can be used to provide more accurate defect detection. For example, the measurements from multiple types of transducers can be compared with a matrix of threshold values to evaluate whether a  
20 defect has been struck. In other words, if one transducer produces a particular reading, a corresponding threshold value can be used for the other transducer to evaluate whether or not a defect was struck. A correlation of the measurements from  
25 the multiple transducers should reduce the number of false positive readings and false negative readings. Thus, measurements can be made with a greater confidence level.

An embodiment of glide head 132 with  
30 different types of defect detecting transducers is depicted in Fig. 7. Glide head 132 includes rails 400, 402 along air bearing surface 404. Thermal transducer 406 is located on rail 402. Electrically

conductive pads 408, 410 provide electrical conduction between transducer 406 and the top surface 412 of glide head 132. Pads 408, 410 are connected to resistance measurement circuit 414 for the evaluation 5 of changes in resistance of transducer 406. Pads 408, 410 are located along or near rear edge 416 of glide head 132. Piezoelectric transducer 420 is located on wing 422 along top surface 412. Piezoelectric transducer 420 is connected to measurement circuit 10 424.

Regardless of the particular embodiment for the placement and number of the thermal transducers on the air bearing surface, the thermal transducers generally are formed on the air bearing surface 15 following the contouring of the air bearing surface to form the gross shape of the air bearing surface. The thermal transducers can be deposited using any of the vacuum metal deposition techniques, such as sputtering. Conduction strips and conduction pads can 20 be similarly deposited. Generally, the components are covered with a protective, electrically insulating layer such as diamond like carbon.

The order of processing depends on the approach used to produce the slider from a wafer. In 25 conventional approaches, the air bearing surface is formed from a cut edge of the wafer. In these approaches, the electrically conductive pads can be deposited on the surface of the wafer prior to the slicing of the wafer. The pads are positioned on the 30 wafer surface such that they are along the rear edge of the slider after the sliders are cut from the wafer.

Following the cutting of the individual

sliders, the air bearing surface generally is subjected to one or more stages of lapping (e.g., rough lap, smooth lap and crown lap) to smooth the surface. Lapping generally involves mechanical, 5 chemical and/or mechanical/chemical polishing. Following a desired amount of lapping, the air bearing surface is contoured using thin layer deposition techniques, milling techniques such as ion milling, reactive ion milling or laser ablation, or a 10 combination thereof. Following contouring, the thermal transducers and conductive strips are applied to the air bearing surface. A protective coating then can be applied, if desired.

As noted above, a preferred approach for the 15 production of sliders with thermal transducers on the air bearing surface involve the cutting of sliders from wafers such that the air bearing surface of the sliders is formed from a surface of the wafer. Thus, a greater portion of the slider preparation is 20 performed at the wafer level. In particular, the contouring of the air bearing surface and the placement of the thermal transducers can be performed on the wafer prior to slicing the individual sliders. 25 A portion of a wafer processed to produce sliders configured as shown in Fig. 2 is depicted in Fig. 8.

To form the sliders with the thermal transducers located on the air bearing surface, a plurality of thermal transducers 500 can be applied along the smooth surface 502 of wafer 504, as shown in 30 Fig. 8. Thermal transducers 500 are located on rails 506 contoured onto surface 502. Representative rails 506 are noted in Fig. 8. Additional transducers such as a piezoelectric transducer also can be placed on

the opposite surface of the wafer prior to the slicing into individual sliders.

After completing the desired processing of the wafer surfaces, the wafer is "diced" or sliced 5 along cutting alleys 508, as indicated in Fig. 8, to produce cut faces. A first cut produces a set of rows with each row containing a plurality of sliders. A second cut along each row produces the individual sliders with four cut faces. A small quantity of 10 material is lost along cutting alleys 508 during the slicing process.

Following slicing, any desired lapping of the cut edge is performed. In this processing approach, the electrically conductive pads 510, 512 of 15 the slider are applied along the rear edge on the smoothed cut surface, as shown in Fig. 9. Additional details of the processing of sliders to produce an air bearing surface from a wafer surface is described in commonly assigned and simultaneously filed patent 20 application, \_\_\_\_/\_\_\_\_, \_\_\_\_ to Sundaram et al., entitled "GLIDE HEADS AND METHODS FOR MAKING GLIDE HEADS," incorporated herein by reference.

In order for asperity detection systems to be useful to test discs with different tolerances, 25 glide heads generally are designed to have fly heights that depend on the linear velocity of the slider relative to the disc surface. The fly height is selected such that asperities larger than a tolerance value strike the glide head and preferably strike the 30 thermal transducer. The linear velocity is set accordingly.

Tolerance levels for asperity detection are generally set lower than tolerances established for

disc flatness in actual operation since fly heights during actual operation can be altered by additional factors including, for example, flutter of the spinning disc, spindle misalignment, high altitudes  
5 and temperature fluctuations. The glide head is swept across the disc surface at a suitable speed such that the relevant portions of the disc surface are examined with the glide head. The rotation rate generally is varied as the asperity detection slider is moved to  
10 different radial positions along the disc to maintain the relative linear velocity approximately constant.

The embodiments described above are intended to be illustrative and not limiting. Additional embodiments are within the claims below. Although the  
15 present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.